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REPORT

of

COMMITTEE ON THESIS

THE undersigned, acting as a committee of the Graduate School, have read the accompanying thesis submitted by Royal N. Chapman,

for the degree of Master of Arts

They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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THE EXTERNAL MORPHOLOGY OF AGRILUS BILINEATUS.

A Thesis Submitted to the Faculty of the
Graduate School of the University of Minnesota

by

Royal N. Chapman

In partial fulfillment of the requirements
for the degree of Master of Arts.

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The External Morphology of Agrilus bilineatus.

Introduction.

Agrilus bilineatus belongs to the famous family of metallic wood-boring beetles, the Buprestidae, which have received a good deal of attention from collectors, because of their attractive form and color, and from economic entomologists, because of their destructive habits. More than a thousand species of the genus Agrilus have been described from all parts of the world, generally with only a brief description of the adult in terms of the most evident characters, and only in a few cases do we have descriptions of the larva and pupa.

The neglect of the Buprestidae in this respect has not been exceptional, as may be seen from the works of Hopkins[1] on the Scolytid beetles, which stand out almost alone as an example of a work on the morphology of a group of beetles. Considerable attention has been given to organology and the morphology of special regions by Verhoeff[2], Heymons[3], Snodgrass[4], and others, but the morphology of Coleoptera in general is still an open field.

The object of this paper is to give a general description of the external morphology of Agrilus bilineatus with the view of establishing a type which will serve as the beginning of a comprehensive work on the Buprestidae. It is realized that in many respects the work is incomplete

1. Hopkins, 1909, 1911, 1915.
2. Verhoeff, 1894.
3. Heymons, 1896-1899.
4. Snodgrass, 1909.

and that some details of the anatomy will require a more extensive study in order to fix the true homologies with other insects.

Some points are especially striking and these have been given more exhaustive treatment. The telson has been found and described, making eleven abdominal segments in all stages of the life history of the beetle, instead of ten as have usually been described. This interpretation is in accordance with the conclusions of the more recent anatomists and embryologists with regard to other groups of insects.[1]

The abdominal pleurites of the adult have been worked out in comparison with representatives of other families of beetles and it has been found that the term hypopleurite has formerly been applied to a part of the sternite. The part of the sternite which Hopkins[2] called the hypopleurite has been termed " the dorsal area of the sternite." This area was present in all the beetles studied, while the hypopleurite was often membranous and apparently absent, which probably accounts for the former confusion.

The external genital organs have been described with special reference to their homologies with the normal abdominal sclerites. The condition met with in Agrilus bilineatus is a comparatively simple one and the ontogony seems to offer conclusive evidence as to their homology. For this reason it seems that they would offer a much better type for the

1. Janet, 1909.
2. Hopkins, 1909.

study of this perplexing question than a specialized type such as the Scolytoidea[1] or the Scarabeidae[2] which have received so much attention.

The most interesting point brought out is the very similar relation between the head and prothorax of the larva. The larvae of the Buprestidae are popularly known as flat-headed borers, but the majority of authors have stated that the head is very small and that the prothorax is very large. Westwood in 1839 was in doubt about the prothorax and suggested that in some cases the head might be retractile into the prothorax. No other reference to this has been found, and the recent authors on general entomology[3] and those on Coleoptera[4] all refer to the larvae of this family as having a small head and a large prothorax. The head has been found to be surrounded by the prothorax and considerable space in this paper has been given over to the description of this condition and an explanation of the functional advantage of such a peculiar condition has been offered.

In terminology Hopkins[5] has been followed in general, in so far as the terms applied to such a specialised group of beetles as the Scolitoidea can be applied to Agrilus. Verhoeff's[6] terms for the external genital organs have been used because of their general acceptance and their applicability. In the study of the thorax two courses were open: to follow Berlese[7] and apply his terms only in so far as parts were found

1. Hopkins, 1915.
2. Smith, 1888.
3. Kellogg, 1908; Comstock, 1913.
4. Blatchley, 1910.
5. Ibid.
6. Verhoeff, 1894.
7. Berlese, 1909.

to be homologous with certain types already worked out, or to follow Snodgrass[1] using for the most part the terminology of Audoin, and applying the terms to parts which seem to be analogous with those of certain types without pretending to designate homologous subdivisions of the thorax. The latter course has been chosen partly because it is the usual and more tangible one, and partly because Berlese's theory has not been so generally accepted and requires much more intensive study. Great difficulty has been experienced in interpreting some of the thoracic subdivisions, especially the axillary solerites, and the descriptions given are what have seemed to be the most consistent interpretation in accordance with the types described by Snodgrass.[1]

The larval head and mouth parts have been homologised with those of generalised insects so far asspossible. The adult head conforms in general with those described by Hopkins[2] and the terminology used by Comstock and Kochi[3] has been applied.

The order in which the various regions of the body are treated is the reverse of the usual one, namely to consider the head, the most complicated region, first, and then the thorax and abdomen. The abdomen is here taken up first because its segments are of the simplest type. The thorax is next in order of specialization and it is taken up secondly. The head with its extreme specialization is discussed last. Furthermore

1. Ibid.
2. Ibid.
3. Comstock and Kochi, 1902.

each region is considered first in the larva, then in the pupa, and finally in the adult. A better understanding of the true condition is gained by thus taking up the simplest part, the abdomen, in the simplest form, the larva, and following it to its highest development in the adult, before proceeding to the more specialised regions which are treated in the same way.

The descriptions are brief since all of the parts are fully figured. The thoracic appendages have seemed to offer no special points of interest and little is said of them. Where two sets of terms have been used the newer ones have been placed in parentheses.

General Description.

Weber first described Agrilus bilineatus in 1801, and a brief description which has been passed from one author to another, with occasional additions may be quoted from Blatchley[1], as follows: "Elongate, moderately robust. Above black, often with a slight greenish tinge; sides of the thorax and a narrow stripe reaching from the humerus to beyond the middle of each elytron clothed with dense yellow pubescence; distinctly narrower at base; sides nearly straight on apical half, sinuate near hind angles, which are rectangular; disk with a vague median

[1] Blatchley, Ibid.

and a short lateral oblique impression on each side, finely transversely strigulose-punctate. Elytra broadened behind the middle, tips rounded serulate, surface densely granulate. Prosternal lobe truncate in front. Length 6-9 mm."

The larvae have been very briefly described by Chittendon and by the author[1] in a previous paper. They are often as long as 24 mm. at maturity, and are of a yellowish white color. The only heavily chitinized parts of the larvae, aside from the head, are the prothoracic sclerites, as described later, and the tenth abdominal segment. The pupae are white or yellowish white, in some cases, and very similar to the adult. Those figured show the segmentation as it appears in a representative but rather advanced stage. The exposed sclerites of the adult are inflexible and covered with very fine hairs which are found even on the parts which are covered by the elytra when at rest, and out onto the tarsal joints.

The Abdomen.

Ten abdominal segments, followed by a telson, may be recognised in each stage of the life history of Agrilus bilineatus. As is usual the anterior and posterior segments are the more specialised. In each case there are eight spiracles on the first eight segments.

1. Chapman, R. N., 1915.

The Larva.

The larval abdomen (Figs. 1, 2, and 3) is sub-cylindrical, although when the dorso-ventral muscles contract it may become quite flat. The dorsal and ventral surfaces are so similar that they can be distinguished only by the presence of the spiracles on the dorsal side. The abdomen of an average larva would measure, at maturity, about 15 mm. in length and 2 mm. in width. It is of about equal width throughout, having the sides of each segment parallel, but for the rather abrupt intersegmental constrictions. In case of contraction due to the action of the longitudinal muscles, the segments become telescoped into each other posteriorly. This causes the posterior part of the segments to appear wider than the anterior part. The tenth segment is normally more or less contracted into the ninth segment.

Fine hairs are scattered about over the lateral surfaces of all the abdominal segments, especially on the tenth segment, where they are so numerous and large that they may be seen with the naked eye. (Fig. 2) The second to the seventh segments, inclusive, are very uniform in every way. The first segment differs from them in being shorter by about one quarter of their length, while the eighth is only about one half of their length and is narrowed anteriorly. The posterior segments, which do not bear spiracles, are quite different, being shorter and so united as to

appear almost as one segment. The ninth segment is the shortest one in the abdomen, although the tenth is but slightly longer due to the forceps which project posteriorly from it.

On the first nine segments there is nothing to suggest definite longitudinal divisions. Sections show that there are lateral areas on both dorsal and ventral surfaces where a chitinous roughness can be seen. These areas mark the attachment of the dorso-ventral muscles which extend nearly the entire length of each segment in four or five indefinite rows. (Fig. 3) On the ninth segment there are but two or three such rows. In case of the contraction of the dorso-ventral muscles these areas of attachment, together with the spiracles which are situated in the median anterior part of them, become depressed. When in this condition the parts lateral to these areas appear like separate divisions. (Fig. 2)

The presence of the spiracles in the dorsal areas indicates that the pleurites are dorsal. Since there are no divisions between these and the mid-dorsal region it seems that the pleurites and tergites are continuous and that the apparent lateral divisions have no particular significance as such. The same may be said of the relation between the sternites and pleurites. For convenience an arbitrary division might be made and the dorsal region called the tergal area and the ventral the sternal area. The larvae of this species are not to be compared, in this respect, with

those of other groups, such as Dendroctonus,[1] where four definite longitudinal divisions are clearly indicated.

What has been said of the indefiniteness of longitudinal divisions is in general true of transverse divisions of segments. When the abdomen is shortened by the action of the longitudinal muscles transverse wrinkles do appear, but they are indefinite and lack uniformity in the different segments. Again a comparison with larvae which show definite transverse divisions seems unwarranted without further study of closely related forms.

The tenth segment has a chitinous covering composed of two sclerites which meet in sutures at the mid-dorsal and mid-ventral lines. Anteriorly the chitin may be hardly noticeable, but posteriorly it is quite thick, especially on the forceps. (Fig. 3) These lateral sclerites diverge posteriorly, forming a wide crotch, and continue as the two halves of the forceps, which are hollowed out on the median side like two blunt pens. The forceps together with the sclerites are capable of lateral motion. In larvae of the first instar there is a chitinous ridge extending dorso-ventrally across the median side of each half of the forceps, (Fig. 4) while in older larvae there are two such ridges which give the forceps a notched appearance on the median side.

Between the forceps and on either side of the anal opening there are two lobes appearing as if slightly chitinized on their edges and bearing

1. Hopkins, 1909;

small hairs. (Fig. 3) The muscle attachments in these two lobes are similar to those of other segments and they are considered as the telson. Janet[1] has stated that, although pretelsonic segments may atrophy, the telson, which is the terminal segment, is always present, often as the anal plates. From this there would seem to be little doubt but that these lobes are the terminal segment or the telson.

The Pupa.

The abdomen of the pupa (Figs. 5-8) is like that of the larva in having ten segments plus the telson, but the form is essentially like that of the adult, and the specialigation has progressed to include an additional segment at either end of the abdomen. The segments are clearly divided into tergites, pleurites and sternites. The tergites are flat, nearly rectangular, meeting each other in sutures which curve posteriorly, and are a little more than twice as broad as long. Each of the three posterior segments is slightly withdrawn into the segment anterior to it.

The first tergite is the shortest, the second is a little longer, the third to the sixth are of about equal length, while the others are greatly lengthened posteriorly. The last four tergites are spade shaped, become progressively shorter, and so overlap one another that only the seventh is seen in its entirety. The tenth tergite is very small and is situated under the ninth tergite where it may be made out only with dif-

1. Janet, 1909.

ficulty. Aside from a thickened band extending around the posterior margins of the seventh, eighth and ninth tergites, there are no distinctive markings.

The sternites are quite extensive in the pupa reaching to the dorsal surface of the abdomen. The coxal cavity is so enlarged that all but the sides of the first sternite has disappeared and the second sternite has been reduced. The third to the sixth sternites are of uniform width but of diminishing breadth, while the next three sternites, like the corresponding tergites, are produced posteriorly, overlapping one another. In the male the ninth sternite is shaped much like that of the eighth, but folded dorsally and is followed by a thick tri-lobed part, (Fig. 7) evidently the tenth sternite, which is modified for reproduction. In the female the ninth sternite is folded dorsally on either side. Within the folds of the ninth sternite a thickened structure is found which resembles that found in the male except that it is smaller and bi-lobed. (Fig. 8) The telson is difficult to see as it is withdrawn between the tenth tergite and sternite.

The pleurites are present in two series. The hypopleurites are but little wider than the spiracles anteriorly while posteriorly the lateral suture sweeps outward as shown in Fig. 5. The epipleurites are narrow and rectangular. The spiracles are elevated about .25 mm. above the sur-

face of the pleurites and are situated well toward the anterior of the segments.

The Adult.

The adult abdomen (Figs. 9-11) is like that of the pupa in form, except that the three posterior segments have been entirely withdrawn so that under normal conditions the seventh segment appears as the terminal one. (Fig. 9) The tergites are quite flat and slightly sunken below the sides of the sternites. The more generalised sternites are large, covering not only the ventral and lateral sides but also being recurved mesially at each side on the dorsal surface of the abdomen. The pleurites are present on either side in two series: epipleurites and hypopleurites.

The first seven tergites are heavily chitinized and pigmented, whereas the posterior three are unpigmented, flexible, and covered with hairs. The first two tergites are closely united to each other and to the metathorax. The margin of the first one is recurved to meet the metatergum, but the margins of the next five are nearly straight and the others are modified as shown in Fig. 9, the seventh ending in a projecting carina. The first five tergites have a sensory pit on each side just within the anterior margin. (Fig. 17)

There are large prephragmas on the second and seventh tergites where the two main points of articulation are located; the first two segments are

so closely united to the metathorax that the thoracic-abdominal articulation is functionally between the second and third tergites. The seventh tergite is capable of being lifted when the reproductive organs and the terminal segments are protruded. (Fig. 15) The lateral prephragmas of the eighth and ninth segments are extended to articulate with the corresponding sternites. (In the case of the female the ninth tergite articulates with the ovipositor.) The tenth tergite is very small and is placed beneath the ninth tergite where it is made out with difficulty.

There are ten sternites, nine of which appear as such in the male and only eight in the female, while the posterior ones are modified for reproduction. Seven of the sternites, (Fig. 10) like the corresponding tergites, are pigmented and thickly chitinized, while the others are unpigmented, flexible, and bordered with hairs. The first sternite is greatly reduced by the encroachment of the coxal cavity, within which it is seen with difficulty as a small chitinous strip, fused with the inter-coxal process mesially and laterally, where it is widest, it is fused with the large sclerite formed by the next three sternites. The dorso-lateral edges of the first seven sternites are bent inward along a straight line forming dorsal areas. (Fig. 17) These areas in Agrilus bilineatus are marked by a strip of yellowish hairs and the angle at which the area is inflected is produced posteriorly in all but the seventh segment where it becomes continuous around the end.

The second sternite extends anteriorly, possibly with the first sternite, to form the inter-coxal process. (Fig. 10) In the large sclerites formed by the union of the second, third, and fourth sternites the suture of the second and third may be seen in newly emerged adults but it is invisible later, while that between the third and fourth remains visible, as a depression. In males there is a longitudinal depression along the mid-line of the portion representing the third and fourth sternites. In the fourth and fifth sternites there are sensory pits similar to those noted in the tergites. The abdomenttapers down in the region of the fifth, sixth, and seventh segments, the latter functioning as the terminal segment.

In males the posterior border of the eighth sternite is incurved at the sides of a median carina. (Fig. 18) In females it is rounded posteriorly much like the seventh sternite. (Fig. 19) The ninth sternite is present as such only in the males where it is a long spade shaped sclerite with a median carina posteriorly and long lateral apodemes anteriorly. At the sides there are membranes which appear to represent the hypopleurites.

It has already been stated that the pleurites are present in two series, epipleurites which bear spiracles and hypopleurites. (Fig. 17) The two series are separated by a pleural membrane along the pleural suture and they are closely articulated with the tergites in the case of the epipleurites and with the dorsal areas of the sternites, in the case of the hypopleurites.

There seems to have been some confusion with regard to the hypopleurites and the dorsal areas of the sternites. The latter have been described and figured as the hypopleurites.[1] A close examination shows that they are not separate sclerites but only inflected portions of the sternites. In a study of representatives of various groups of beetles the dorsal areas of the sternites were found in all the species examined while the pleurites varied greatly. In some cases the pleurites were entirely membranous (Carabidae), in others the epipleurites were chitinised and the remainder membranous (Cerambicidae, Tenebrionidae, and Ipidae), in still others the hypopleurites were chitinised and the remainder membranous (Hydrophilidae), and in Agrilus bilineatus both series are chitinised and distinct.

There are eight pairs of spiracles, each with tracheae and apparently functional. The first is large and elliptical, while each succeeding pair is smaller and more round; the eighth is quite small and round and is covered by the seventh tergite. The first epipleurite is divided transversely so that the spiracle and the anterior part appear to belong to the metathorax.

The pleural suture passes diagonally across the pleural area so that the first epipleurite is the broadest of that series and the seventh is the narrowest. On the other hand the third hypopleurite, which is the first one distinguishable, is very narrow while the seventh is wide. From a study

1. Hopkins, 1909.

of other beetles it is concluded that this variation is dependent upon the size of the spiracles. In this case the largest spiracle is tha anterior one and the epipleurites vary directly in proportion to it. The hypopleurites vary inversely in proportion to the size of the spiracles. In Hydrophilus where the anterior and posterior spiracles are the largest the terminal hypopleurites are the narrowest.

The seventh and eighth epipleurites are completely fused to the tergites but are clearly defined by a depression. (Figs. 11, 18) In the ninth and tenth segments the position of the epipleurites is not noticeable. The seventh hypopleurite is incompletely fused to the sternite while the succeeding ones seem to be completely fused to the corresponding sternites.

The External Genital Organs.

In both sexes the external genital organs are normally withdrawn from sight together with the terminal abdominal segments. In newly emerged adults and during copulation and oviposition, in mature adults, the organs and the terminal segments are protruded. These parts may be exposed artificially in fresh or slightly macerated specimens by gently squeezing the abdomen with a pair of forceps. (Figs. 15, 16)

For the description of the male organs it has seemed best to adopt the terms used by Verhoeff[1] rather than some of the more recent ones, because

1. Verhoeff, Ibid.

the terms seem to be more applicable to this beetle. For the female the terms used by Hopkins[1] have been used where possible.

The chitinised penis is enclosed by the parameron. (Fig.15) At the distal end the penis is pigmented, heavily chitinised, and forms a complete tube which is quite sharp at the end. Proximally the chitinous part is trough shaped and is articulated to the parameron by two femora penis. The ejaculatory duct is enclosed in the trough and is continuous with the tubular end of the penis.

Proximally the paramera form a complete ring while they appear to be separated on the mid lines. At the distal end they closely invest the penis and then diverge. At the tips there are lateral areas which are flattened and covered with hairs. The dorsal part is extended proximally and the ventral part is bent dorsally, giving the whole structure the appearance of a slipper, when seen from the side.

The tenth sternite is not present as such in the adult although it was seen as a trilobed structure in the pupa (Fig. 7), where, during metamorphosis, the middle lobe was seen to form the penis while in the two lateral lobes the paramera developed. From these observations it seems safe to conclude that the paramera represent the lateral lobes of the sternite while the penis represents the median lobe plus the ejaculatory duct. The presence of the basal plate seems doubtful although two thin mem-

1. Hopkins, 1915.

branous laminae were found. The whole apparatus rests upon the ninth sternite to which it is in part attached. Since the anterior lateral apodemes of the ninth sternite are recurved and articulated to the tergite, the opening of this segment tends to push the apparatus out posteriorly.

The external genital organs of the female seem more complicated than those of the male. (Fig. 16) The ovipositor is a long tube with scattering hairs on the distal part and with a pair of genital palps placed at either side of the opening. As has been mentioned the anterior lateral apodemes of the ninth tergite are greatly lengthened and articulate with the ovipositor. In the walls on each side of the latter there are two ventral rods extending out from the perpendicular rod, one long one reaching nearly to the end where it meets its fellow of the opposite side at the mid-ventral line, and a shorter one which ends in the lateral wall. On the dorsal side there are two rods which reach from the distal end to a point near the perpendicular rod.

Here as in the case of the male the homology of the parts is suggested by the ontogony. It has been noted that there are three sets of rods in the ovipositor, two pairs of ventral ones which articulate with the ninth tergite by means of a perpendicular rod in a way not essentially different from that of the ninth sternite in the male, and a dorsal, more distal pair, which do not articulate with the ninth tergite. Com-

paring this condition with the one met with in the pupa, where the tenth sternite was a bilobed structure (Fig. 8), it is found that the dorsal rods, together with the genital papillae, seem to develop from these lobes. The ninth sternite was present in the pupa and its sides were reflected dorsally about the tenth sternite, which condition might well lead to the fusion of the ninth and tenth sternites to form a tube. The unemerged adult shows an intermediate condition where the dorsal part of the ovipositor with the dorsal rods and genital papillae are fused with the lower part but still some distance dorsal to it.

When the ovipositor is retracted into the body it lies with the proximal end within the fifth segment. When it is protruded the ninth tergite lifts up, the eighth sternite is depressed and by a bending of the ninth tergal rods the ovipositor is forced out. Small muscles in the wall of the ovipositor seem to make it possible for the structure to bend in any direction.

The Thorax.

The Larva.

The thoracic segments of the larva vary greatly both in shape and size depending upon their state of contraction. (Fig. 1) Unlike the abdominal segments the two posterior segments contract mainly in a longi-

tudinal direction. The muscles which bring about the great contraction of which these segments are capable are diagrammed in Fig. 20. The thorax is entirely covered with small spines which are directed posteriorly. (Fig. 21) There are also scattering hairs especially on the sides of the thorax.

The metathorax is short, symmetrically rounded on all sides, (Fig.1-3) no spiracles, appears the same on the dorsal and ventral surfaces, and is not subdivided. The anterior abdominal segment telescopes into the posterior of the metathorax when the body contracts, whereas the two posterior thoracic segments only abut against one another under these conditions. (Fig. 22)

The mesothorax appears much like the metathorax except that it possesses a pair of spiracles which are situated ventro-laterally. When contracted the mesothorax is partly overlapped by the prothorax dorsally, while ventrally it overlaps the prothorax. (Fig. 21) These two segments are so closely associated when contracted that it is sometimes difficult to distinguish them from each other, for under these conditions, the spiracles appear to be situated on the ventral side of the prothorax.

The prothorax is very highly specialised in connection with the head which has so invaginated into it that only the mouth parts, the post labrum and the gula are exposed, while the remainder of the head together

with the anterior half of the prothorax are enclosed by the posterior portion of this segment. (Fig. 20) The general shape of the prothorax is like that of a double walled ring, the sides of which have been somewhat flattened together, leaving a space between the inner walls in which the head is fitted. (Fig. 24) The inner wall of the prothorax is in contact with the head except at the mid-ventral line, posterior to the gula, and posterior to the frons at the mid-dorsal line. (Fig. 22) The gula is not invaginated into the prothorax, the frons is invaginated about half the length of the prothorax, and the sides of the head extend to the mesothorax. (Fig. 24) A further discussion of the relation of the head to the prothorax is given in connection with the description of the head.

The Pupa.

The pupal thorax, (Figs. 5-7) like the other segments of the body, is entirely different from that of the larva. The wing pads cover the metathoracic pleurites and legs with the exception of the tarsi, and the first two pairs of legs are folded so close together that they obscure the mesothoracic pleurites.

The metathorax is the largest of the three segments. The tergum is rectangular with areas representing the scutum, scutellum and postscutellum. (Fig. 5) The prescutum has not been made out and probably is not present. The first two divisions, scutum and scutellum, would represent

the notum according to Snodgrass[1] and the third, the postscutellum, would represent the pseudonotum. It has been stated that the pseudonotum is not present in Coleopterous pupae, but this subdivision answers to the description of the pseudonotum in the adults. It is just posterior to the scutellum, which bears the axillary cords, and its lateral processes articulate with the metathoracic pleurites. Furthermore the pseudonotum of the unemerged adult can be seen to have developed within this part.

The scutellum extends forward, as is characteristic of Coleoptera, and the scutum is represented by two lateral lobes. The metathoracic wing pads lie obliquely caudo-ventrad under those of the mesothorax, and are seen only at their tips. The wing tracheation has not been studied in detail but is apparently like that of the adult which is figured. The axillary sclerites were not distinguished.

The metasternum (Fig. 7) projects anteriorly between the mesocoxae and is notched in the median line where it articulates with the mesosternum and the process of the pro-sternum. This anterior projection evidently represents the pre-sternum which is fused with the large sternum. Posteriorly the sternellum, indicated by a transverse suture, projects between the meta-coxae and articulates with the inter-coxal process of the abdomen.

The pleural divisions, the episternum and epimerum, are seen as

1. Snodgrass, 1909.

longitudinal subdivisions upon removal of the wing pads.

The mesothorax is the smallest of the three segments. The tergum is rectangular and is quite clearly divided into a scutum and a scutellum. The latter bears the axillary cords and extends anteriorly partially dividing the scutum into lobes. The triangular prominence is well developed in the median line. The pre-scutum has not been distinguished nor have the axillary sclerites. The wing pads are long and narrow.

The meso-sternum is small and so concealed by the process of the prosternum that little of it can be seen without dissection. The sub-divisions are not recognisable as such, although there is an impression into which the prosternal process fits. The meso-sternum forms only the anterior border of the meso-coxal cavities.

The pleurites show a definite division into an episternum and epimerum. In the later pupal stages the anterior border of the episternum becomes inflected to form the posterior wall of the cavity occupied by the prothoracic femora. The trochantine is not distinguishable.

The prothorax is about as large as the metathoracic segment. The pleural and tergal divisions are fused into a large pronotum. Dorsally the pronotum is broad and convex at the anterior end, while it is narrower and nearly flat at the posterior where the margin is quite pronounced. The lateral angles of the posterior margin are nearly rectangular . There is a long

flat vertical area at the point of union between the pleural and tergal divisions, (Fig. 6) but otherwise there are no sculptural markings. The pleurite is narrowed ventrally forming a triangle, the dorsal side of which is fused with the tergum, the anterior border articulates with the pro-sternum, and the posterior border articulates with the meso-pleurum, forming the cavity in which the prothoracic femora rests.

The sternum is triangular, tefminating posteriorly in the pronounced pro-sternal process, and anteriorly in a large crescent shaped pre-sternal division which reaches to the tergum laterally and articulates with the head anteriorly.

The Adult.

The thorax of the adult is cylindrical and is over one third as long as the entire insect. The first and third segments are of about equal size, the former being largest dorsally and the latter largest ventrally. In the metathorax the tergum has the four usual divisions. (Fig. 25) The prescutum presents the large prephragma, the lateral lobes of which are well developed. The scutum is divided into two lateral lobes by the median prolongation of the scutellum. The latter has the "Y" shaped entodorsum which is characteristic of Coleoptera and is extended laterally in the inconspicuous axillary cords. The pseudonotum is narrowed laterally into pleural processes which articulate with the metapleura. The postphragma is well developed.

There are three axillary sclerites, a pleural disc, and a median plate concerned with the articulation of the wing. The scapular plate (first axillary) and the sub-scapular plate (second axillary) are closely associated and have the usual articulations; the former with the subcostal vein and the latter with the head of the radius. The median plate is confusing due to its shifting of position with every movement of the wing. Its general position is lateral to the sub-scapular (first axillary) plate and at the head of the median vein. The flexor plate (third axillary) lies lateral to the pleural disc and at the heads of the cubital and anal veins.

The venation, as figured, is quite typical of the Coleoptera. (Fig. 9) The wing is folded only in the longitudinal direction since it is no longer than the elytron.

The metasternum is quite large and not essentially different from that of the pupa. (Fig. 16) The pre-sternum projects between the mesocoxae where it is forked to receive the mesosternum and prosternal process. The sternum has lateral lobes and evidence of three sutures, one at the median line, and two lateral ones reaching forward from the sternellum. The sternellum contributes to the formation of the coxal cavities and projects posteriorly between the cavities where it is forked to receive the inter-coxal process of the abdomen. The coxae are long and transverse.

The metapleurum is rather complicated. (Fig. 26) It is seen ventral to the elytra as a longitudinal rectangle which is continuous, under the elytra, as a thin part, dorsal to which there is a third triangular part. There is no external evidence of a pleural suture on the exposed part, but on the median side the pleural apodeme is found to extend from the posterior ventral border diagonally across to the wing process. The episternum would therefore[1] be confined to the triangular area ventral to this apodeme. The epimerum has two subdivisions, a ventral one, part of which is exposed, and part of which is covered by the elytron, and a triangular dorsal division which is entirely covered by the elytron. The latter is so closely articulated with the first abdominal epipleurite that they appear almost as one sclerite. The dorsal margin of the exposed portion of the pleurite forms a longitudinal ridge over which fits the elytron when at rest. Anteriorly the ventral subdivision of the epimerum and the episternum unite to form the coracoidal condyle or wing process. The preparapterum forms the clavicle condyle and is so fused to the anterior of the episternum that it gives the appearance of a double wing articulation. (Fig. 26)

In the mesothorax the tergum is triangular with the base directed anteriorly where its convex margin articulates under the pronotum. (Fig. 27) The lateral margins are depressed so that the wing articulations and the

1. Snodgrass, 1909.

notal processes are on a lower level than the remainder of the tergum. The subdivisions are difficult to detect and are here given in accordance with the interpretations of Snodgrass.[1] The prescutum is the large area just posterior to the prephragma which bears the anterior notal processes and extends posteriorly to meet the scutellum. The depressed lateral areas represent the scutal lobes. The scutellum is confined to the prominent triangular area at the posterior including the posterior notal processes, from which the obscure axillary cords extend to the elytra. The post-scutellum or pseudonotum is not distinguishable.

Three axillary sclerites and a pleural disc are present. The scapular and sub-scapular plates (first and second axillaries) are fused and the flexor plate (third axillary) lies just anterior to the axillary cord. The basal process of the elytron is elongated and so twisted that the costal head is ventral and the subcostal head is dorsal and slightly posterior to it when the elytron is extended. (Fig. 28) The elytron has a marked basal declevity which articulates with the pronotum, an anal fold which fits between the lateral side of the meso-scutellum and the median side of the scutal lobes of the meta-thorax when at rest. (Fig. 9) The anal margin is nearly straight while the costal margin is concave, making the elytra narrower near the middle. The costal fold covers the dorsal sub-division of the epimerum and the costal groove fits over the edge of

1. Snodgrass, Ibid.

the entire pleurum anteriorly and along the dorsal area of the abdominal sternites posteriorly. The anal grooves of the two elytra dove-tail together. (Fig. 29) The elytra are depressed dorsally near the humeral angle and are serrulate at the apex. The entire dorsal surface is granulate with a strip of yellowish white hairs extending from the humeral angle to the median line near the apex. (Fig. 9)

The meso-sternum is small with no distinguishable sub-divisions and is deeply impressed along the median line where it articulates with the pro-sternal process. The trochantine may be seen externally and the coxae are contacte. (Fig. 10)

The meso-pleurum is distinctly sub-divided by an oblique pleural suture into the episternum and epimerum. (Fig. 30) The latter is the narrower part which extends more dorsally than the episternum. The anterior margin of the episternum is inflected as in the pupa. The spiracle is situated anterio-dorsal to the episternum. There is a small plate just anterior to the spiracle which evidently belongs with the pre-phragma. (Fig. 27) The trochantine may be seen externally between the angle of the pleurum and the coxa.

The prothorax is practically the same as in the pupa. (Figs. 9-11) There are no divisions indicated either between or within the tergum and pleurum. The surface of the notum is transversely strigulose with two

yellowish white pubescent stripes, along the lateral impressions, which become continuous with the stripes on the elytra. The pronotum is widest and most convex anteriorly and the posterior angles are almost rectangular. The anterior margin bears a line of black hairs, whereas the posterior margin is finely serulate. The pleurum is triangular, quite smooth, and slightly concave.

The pro-sternum is very broad anteriorly with a distinct episternum. The long posterior prosternal process evidently represents the sternellum although there is no suture separating it from the sternum proper. The trochantine is small, and may be seen externally between the coxae and the ventral angle of the pleurum. The coxae are contiguous as in the mesothoracic legs.

The Cervical Sclerites or Microthorax.

There are two small rod-like sclerites on either side, articulating between the occiput and the presternum of the prothorax. (Fig. 12) The smaller sclerite is placed obliquely with its lateral end articulating with the presternum and its median end articulating with the longer sclerite. The later lies obliquely when the head is at rest, with the lateral end articulating with the prephragma of the occiput at a point near the gula.

The Head.

The larva.

The larval head exhibits a high functional specialization in connection with the prothorax, which will be more clearly understood if the structure of the head itself is first considered.

Morphologically the head capsule is not difficult to homologise with the more generalised larval heads. (Figs. 31, 32) It is nearly round, horizontal, and is flattened dorso-ventrally. The occipital foramen extends from the frons on the dorsal side, posteriorly around the occipital angles and anteriorly, on the ventral side, to the gula. The lateral expanses on either side are made up of the epicranium and genae which are greatly developed and fused into one sclerite. The gena articulates anteriorly with the gula (hypostome) and mesially with a rather thin phragma-like occiput. The epicranial portion articulates with the frons and antennal sclerite (antennal ring) anteriorly, and mesially with the dorsal division of the occiput which is a well developed sclerite. The geno-occipital apddeme is enlarged at its anterior end to articulate with the gula. The epicranio-occipital apodeme is flat and broad anteriorly and narrow and deep posteriorly, ending in an articular head which meets the geno-occipital apodeme to form the occipital angle. The latter can sometimes be seen through the prothorax.

The triangular frons is marked by a broad frontal apodeme which lies longitudinally in the median line and articulates posteriorly with the occiput and epicranium and anteriorly with the postlabrum (epistoma). The adfrontal[1] sclerites are situated lateral to the frontal sclerite and articulate with the postlabrum. The two jointed hairy antennae are situated between the adfrontal sclerites and the antennal sclerites. The postlabrum is a very heavy transverse sclerite articulating with the antennal sclerites, the gula, the dorsal fossa of the mandibles, and with the labrum through a fold which may represent the clypeus.

The gula occupies a position on the ventral side of the head directly below the postlabrum. In the median line there is an indication of a gular suture, laterally it is fused with the antennal rings and it articulates with the ventral condyles of the mandibles.

The labrum is situated anterio-ventral to the postlabrum and is covered with hairs. (Fig. 35) The mandibles are well developed with three teeth on the median edge, the apical, the median, and the molar. The dorsal fossa of the mandible articulates with the postlabrum and the ventral condyle with the gula. The palpus, lacinia, and distal portion of the stipes of the maxillae are covered with large hairs. The stipes is rather large, whereas the cardo is small. The hypopharynx and labium are closely associated and are covered with hairs. The labial palps are

1. Heinrich and De Gryse.

very small being indicated on either side by three small papillae, the median one of which bears a long hair. The mentum and sub-mentum are indistinct in a large median lobe.

The position of the prothorax about the head has been described. It can be seen in both cross and longitudinal sections (Figs. 21, 24) that where the ectoderm of the prothorax comes in contact with that of the head there is a layer of chitin between, to which both layers of ectoderm are attached. The ectoderm of the head is seen to be continuous with that of the prothorax along the margin of the occipital foramen. At the time of molting the layer of chitin slips out anteriorly from between the head and prothorax, and just after this takes place the prothorax is not attached to the head, except at the occipital foramen. The chitin, which lies between the head and prothorax includes all the head capsule posterior to the postlabrum and gula and may have been secreted by the prothoracic ectoderm as well as that of the head.

The functional advantage of a specialised prothorax in an insect which burrows in the bark or wood is not apparent at first thought. The former view, that the head is small and the prothorax very large, would seem hard to correlate with the burrowing habit, for it would be necessary for the small head, and consequently small mandibular muscles to make a burrow large enough for the passage of the large prothorax.

A prothorax which surrounds the head, as just described, would also seem to be a disadvantage, for it requires a larger burrow than would be necessary if it were situated posterior to the head as is usual.

From the study of the structure of the head and prothorax it has been seen that the prothorax is a sheath in which the head is suspended by means of a system of muscles which allow it to move in any required direction. The diagrams of the head and prothorax (Figs. 20 , 21) show muscles reaching from the anterior part of the outer prothoracic wall to the posterior part of the head which contract to force the head forward in order that the mandibles may bite into the bark. As these muscles contract they necessarily thicken and thus force the sides of the prothorax against the walls of the burrow where they are held firmly by the posteriorly directed chitinous spines which cover the thorax. (Fig. 21) The origin of the muscles is then fixed to the sides of the burrow surrounding the head which is drawn instead of being pushed forward as is usually the case. The position of the head within the prothorax and the chitinous covering of the latter may be seen to be a remarkable adaptation to the burrowing habit.

It has been found that the young larvae get their burrows started when they first break the shell and while they are still within the egg, which is firmly stuck to the bark and gives a leverage to the larva un-

til the prothorax is within the burrow.[1] And if the egg has been loosened the larva gets no leverage and is unable to get a burrow started. On the other hand it has been found that a larva is capable of continuing to burrow after the bark has been removed from around the posterior part of the body, thus demonstrating the power of the prothorax as an organ of locomotion.

The habit which these larvae have of making a detour either into the solid wood or thicker bark, where they moult, is probably due to the fact that when the spiney layer of chitin has been shed and the head capsule, which unites the head and prothorax, is gone, the larva is helpless for a time. The interruptions which are found in the burrows of Agrilus bilineatus are evidence of such periods of helplessness and the widening of the burrows after each of these interruptions will undoubtedly be found to be of great value in determining the instars[1] of these larvae, since a burrow must be of nearly uniform width throughout a given instar inorder to allow the larva to move forward.

The Pupa.

The pupal head is nearly round,(Figs. 5-7) vertical, flattened anterio- posteriorly, and is embraced by the prothorax. The various sclerites are not easily distinguishable especially in the younger

1. Chapman, 1915.

stages. The cranial suture may be present but the other sutures are obscure. The antennal sclerites are indistinct, the antennae are beadlike, but slightly serrate in the younger stages, and lie along the pronotum. The eyes are large, elliptical, and, at first, poorly defined anteriorly. The genae, epicranium, and frons, are fused together. The occiput is visible on the dorsal side and even the occipital foramen may be seen sometimes.

The postlabrum is a thick transverse band from which the rather prominent labrum protrudes. The mandibles, maxillae, and labium are all visible as plump transparent structures. (Fig. 7)

The Adult.

The sclerites of the adult head are more definite than those of the pupa but the general shape and position of the head have not been altered. (Fig. 5-7) The epicranial suture extends from the occipital foramen to the frons. (Fig. 33-34) The surface of the epicranium, frons, postlabrum, pregula, and gena is punctate while that of the occiput and gula is much smoother. The genae, epicranium, and frons are not marked off by definite lines but are represented by rather definite areas.

The postlabrum (epistoma) is distinct with lateral projections, bearing the condyles which articulate with the mandibles, and an an-

terior infolding which may represent the clypeus. The gula is subrectangular, slightly widened anteriorly, and articulates laterally with the ventral margins of the genae.

The antennae are serrate beginning with the fourth joint and are situated in front of the lower margin of the eye, in the antennal sclerites, which are grooved to receive the basal joints of the antennae when flexed. The ventral articulation of the mandibles is apparently on the genae but evidently that portion of the sclerites represents the hypostoma[1] which is not distinct. The submentum is evidently represented by a median bar articulating between the labium and the gula and mentum. The mentum is a large triangular sclerite which articulates with the submentum and gula and almost completely covers the labium and maxillae, so that the mandibles, maxillary palps and the tip of the labium are the only mouth parts which are normally exposed.

The labrum (figure) is inconspicuous, (Fig. 36) chitinous, and covered with longer hairs than the other exposed parts of the head. The mandibles are large and very similar to those of the larvae having the same means of articulation and a large retractor muscle disc and a smaller one for the protractor muscles. The maxillae are more highly developed than those of the larvae. The cardo is long and articulates

1. Hopkins. Ibid.

with the basal portion of the submentum. The stipes and palpifer have fused together, the latter articulating with the basal joint of the palpus, while the former articulates with the cardo. The mesial portion of both articulates with the large flat lacinia which is bordered by papilliform lacinial teeth.

The maxillary palps consist of four joints of which the second and fourth are the largest. The galea is large and flat with large hairs covering its surface. All of the parts of the maxillae, with the exception of the cardo, are covered with medium large hairs. The ligula is evidently fused with the hypoglottis from which two hypoglossal bracons extend to the epiglottis. The ligula and hypoglotis are both covered with long hairs. The labial palps are three-jointed.

Bibliography.

Berlese. A. 1909. Gli Insetti, loro organizzazione, sviluppo, e rapporti cul'uomo. Vol. I. Societa Editrice Libraria, Milano.

Blatchley, W.S. 1910. Coleoptera of Indiana. Nature Pub. Co. Indianapolis.

Broun, T. 1880. Manual of the New Zealand Coleoptera. Pt.I. Wellington, J. Hughes, Lambton Quay.

Chapman, R.N. 1915. Observations on the Life History of Agrilus bilineatus. Journal of Agricultural Research, Vol.III, No. 4.

Chittenden, F.H. 1897. Insect Injury to Chestnut and Pine Trees in Virginia and Neighboring States. U.S. Dept. Agr. Div. Entom. Bul. 7. n.s. P. 67-71.

Comstock, J.H. and Kellog, V.L. 1899. The Elements of Insect Anatomy. Comstock Pub. Co. Ithaca, NY.

..... and Kochi, C. 1902. The Skeleton of the Head of Insects. Amer. Nat. Vol. 36, P. 13.

..... and Comstock, A.B. 1913. A Manual of the Study of Insects. Comstock Pub. Co., Ithaca, N.Y.

Crampton, G.C. 1914. Notes on the Thorax of Winged Insects. Ent. News. Vol. 25. No. I. P.15.

Eichelbaum, F. 1915. Untersuchung über den Bau des mannlichen und weiblichen Abdominalendes der Staphylinidae. Zeitschr. für Wissen. Insectenbiologie. Bd. 10. Heft 10-12.

Escherich, K. 1894. Anatomische Studien über das mannliche Genitalsystem der Coleopteren. Zeitschr. für Wiss. Zool. Bd. 57, P. 620.

Felt. E.P. 1905. Insects Affecting Park and Woodland Trees. N.Y. State Museum, Memoir. 8. N.Y. Educat. Dept. Albany.

Fowler, C. 1887. Coleoptera of the British Isles. Vol. VI. L.Reeve & Co. London.

Heinrich, C. and De Gryse, J.J. 1915. On Acrocerops stigmifinitella Clemens. Proc. Ent. Soc. Wash. Vol. 17. No. 1. P. 6.

Henneguy, L.F. 1904. Les Insectes. Masson et Cie. Paris.

Heymons, R. 1896. Zur Morphologie der Abdomenalanhänge bei den Insekten. Morphologisches Jahrb. Bd. 24, Heft. I P.178.

..... 1899. Der Morphologische Bau des Insektenabdomens. Zool. Centralbl. Bd. 6, P. 537.

Hilger, C. 1894. Zur Morphologie des Kafersabdomens. Zool. Centralbl. Bd. 1, P.385.

Hopkins, A.D. 1909. Contribution Toward a Monograph of the Scolytid Beetles. U.S. Dept. Agr. Bur. Entom. T.S. No. 17, Pt. 1.

.....1911. Contributions Toward a Monograph of the Genus Pissodes. U.S. Dept. Agr. Bur. Entom. T.S. No. 20, Pt. 1.

.....1915. Contributions Toward a Monograph of the Scolytid Beetles. U.S. Dept. Agr. Bur. Entom. T.S. No.17. Pt.1.

Janet, C. 1899. Essai sur la constitution morphologique de la tête de l'insect. Georges Carre et C. Naud, Paris.

..... 1909. Sur morphologie de l'insect. Ducourtieux et Gout. Lomoges.

Kellog, V.L. 1908. American Insects. Henry Holt & Co., New York.

Lugger, O. 1899. Fifth Annual Report of the Entomologist of the State Experiment Station of the University of Minn. St.Paul.

Nüsslin, O. 1912. Phylogonie und System der Borkenkäfer. Zeit. für Wiss. Insektenbiologie. Bd. 8, Heft. 1-7.

Packard, A.S. 1898. A Text-book of Entomology. Macmillan Co. New York.

Smith, J.B. 1888. Notes on the S pecies of Lachnosterna of Temperate North America with Descriptions of New Species. Proc. U.S. Nat'l. Mus. Vol.11. P. 481.

Snodgrass, R.E. 1909. The Thorax of Insects and the Articulation of the Wings. Proc. U.S. Nat'l Mus. Vol. 36, P.511.

..... 1909. The Thoracic tergum of Insects. Entom. News,Vol.20.

Verhoeff, C. 1894. Beitrag zur Kenntnis des Abdomens der mannlichen Elateriden. Zool. Anz. Bd. 17, P.100.

Voss, F. 1904-05. Über den Thorax von Gryllus domesticus. Zeit. für Wissen. Zool. Bd. 78.

Webb, J.L. 1912. Preliminary Synopsis of Cerambycoid Larvae. U.S. Dept. Agr. Bur.Entom. T.S. No. 29, Pt.5.

Westwood, J.O. 1839. An Introduction to the Modern Classification of Insects. Vol. 1. Longman, Orne, Brown, Green, and Longmans, London.

Plates.

The External morphology of Agrilus bilineatus.

By Royal N. Chapman. Master's thesis 1915.

Plate I.

Fig.1. Dorsal view of larva. x 12.

Fig.2. Right side view of larva. x 12.

Fig.3. Ventral view of la rva. x 12.

Fig.4. Posterior segments of newly hatched larva. x37.

Caption.

A.-- Antenna.

F.-- Forceps.

F.n.- Forcep notch.

L.a.- Lateral area.

Lb.- Labium.

M.a.- Area of muscle attachment.

Md.- Mandible.

Ppl.- Prothoracic pleurite.

P.s.- Prothoracic sternite.

P.t.- Prothoracic tergite.

Sp.- Spiracle.

1,2,-10.- Abdominal segments.

Plate I

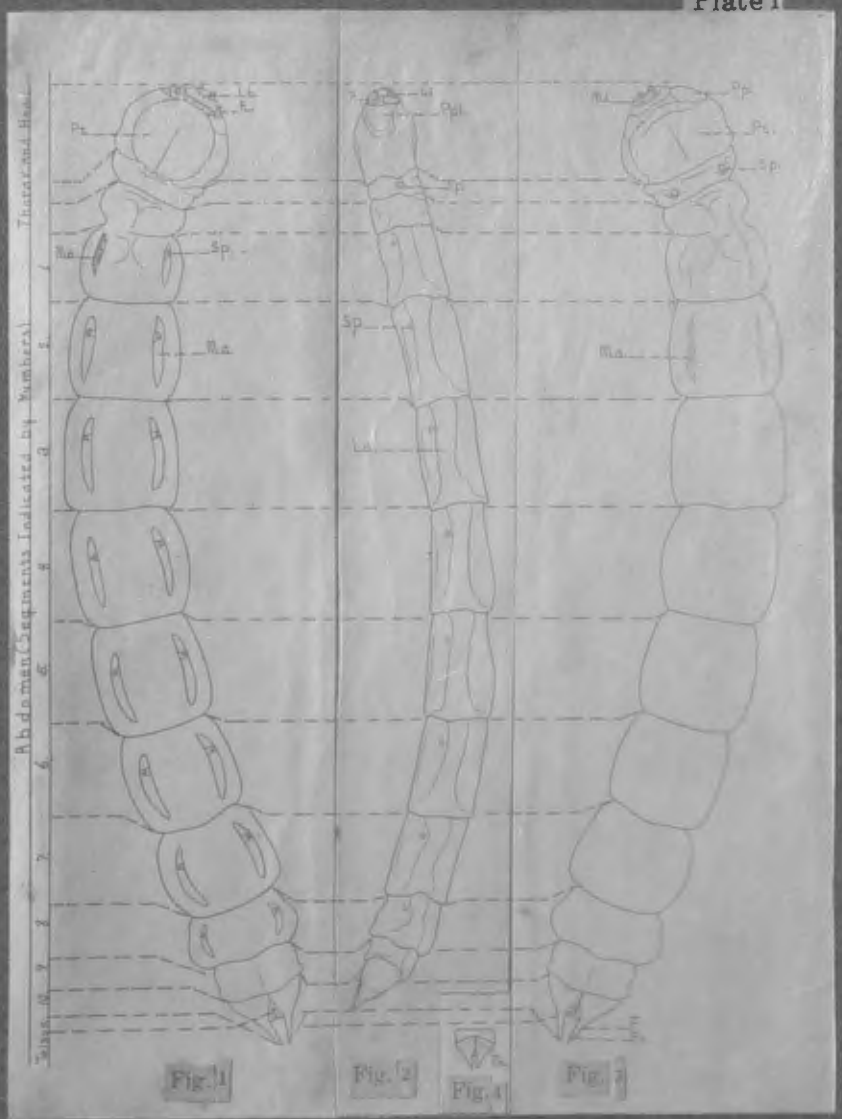

Abdomen (Segments Indicated by Numbers)
Thoracic and Head
Pt.
Sp.
Ma.
Pp.
Pgl.
Lg.
Fig. 1
Fig. 2
Fig. 4
Fig. 3

Plate II.

Fig.5. Dorsal view of pupa. x 12.

Fig.6. Right side view of pupa. x 12.

Fig.7. Ventral view of pupa. x 12.

Fig.8. Ventral view of terminal segments of female pupa. x 12.

Caption.

A.- Antenna.

E.- Eye.

Ep.- Epicranium.

Epl.- Epipleurite.

Eps.- Epicranial suture.

F.- Frons.

F.t.- Femero-tibial joint.

G.- Gena.

Hp.- Hypopleurite.

Ht.- Hind tarsus.

Ic.p.- Intercoxal process.

Lbr.- Labrum.

L.p.- Labial palp.

M.- Mandible.

Ms.l.- Mesothoracic leg.

Mt.c.- Metathoracic coxa.

Mt.p.- Metathoracic wing pad.

Mts.- Metasternum.

M.wp.- Mesothoracic wing pad.

Mx.- Maxilla.

Oc.- Occiput.

Oc.f.- Occipital foramen.

Pl.- Prothoracic leg.

Pn.- Pronotum.

P.p.- Prosternal process.

P.pl.- Prothoracic pleurum.

P.sm.- Postscutellum.

Sc.- Scutum.

Sc.l.- Scutal l obe.

Sm.- Scutellum.

Sp.- Spiracle.

St.- Sternite.

Tr.- Tergite.

Va.- Vertical area of pronotum

Plate II

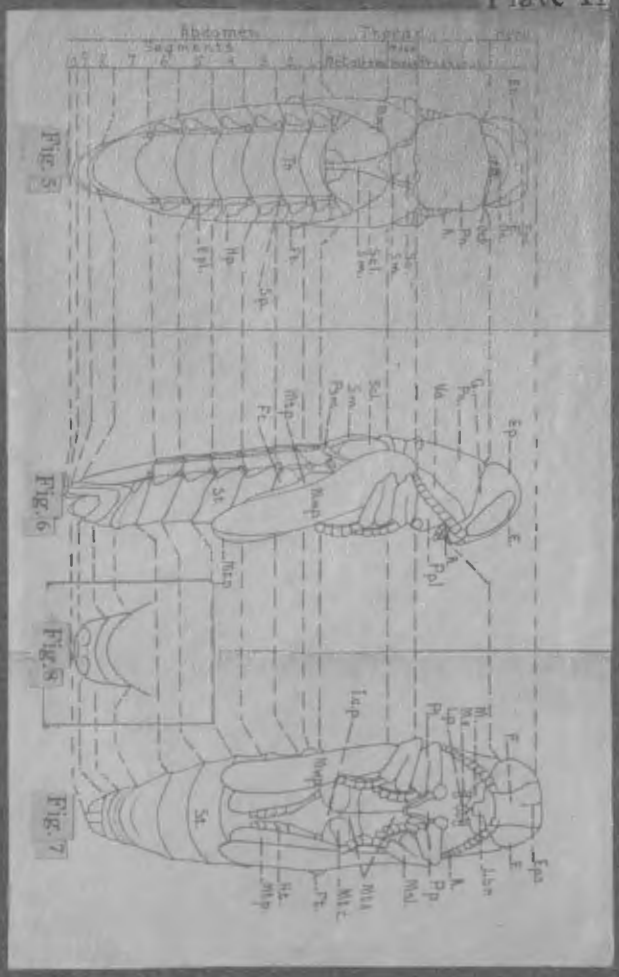


Plate III.

Fig. 9. Dorsal view of adult male. x 13.

Fig.10. Ventral view of adult male. x 13.

Fig.11. Side view of adult male. x 13.

Fig.12. Cervical sclerites or microthorax of adult mal
x 37.

Fig.13.-Claw of adult male. x 37.

Fig.14. Claw of adult female. x 37.

Caption.

A.- Antenna.

Ab.s.1-7. Abdominal sternites.

A.ep.- Abdominal epipleurite.

A.hy.- Abdominal hypopleurtite.

A.pr.- Abdominal prephragma.

C.c.- Coxal cavity.

D.a.s.-Dorsal area of sternite.

El.- Elytra.

E.- Eye.

F.- Femora.

Gr.- Sternal groove of male.

Ic.p.- Intercoxal processes.

L.c.- Long cervical sclerite.

Ms.c.e Mesothoracic coxa.

Ms.l.- Mesothoracic leg.

Ms.pl.-Mesothoracic pleurite.

Ms.pr.-Mesothoracic presternum.

Ms.st.-Mesothoracic sternite.

Mt.c.- Metathoracic coxa.

Mt.c.c.Metathoracic coxal cavity

Mt.l.- Metathoracic leg.

Mt.pl.- Metathoracic pleurite.

Mt.pr.-Metathoracic presternum.

Mt.sn.Metathoracic sternellum.

Mt.st.-Metathoracic sternum.

P.c.- Prothora cic coxa.

P.l.- Prothoracic leg.

Pn.- Pronotum.

Pr.p.- Prothoracic presternum.

P.s.- Presternum.

P.pl.- Prothoracic pleurum.

P.ps.- Prothoracic poststernellum

P.st.- Pubescent stripe.

Sn.- Sansory pit.

Sp.- Spiracle.

S.c.- Short cervical sclerite.

T.- Tibia.

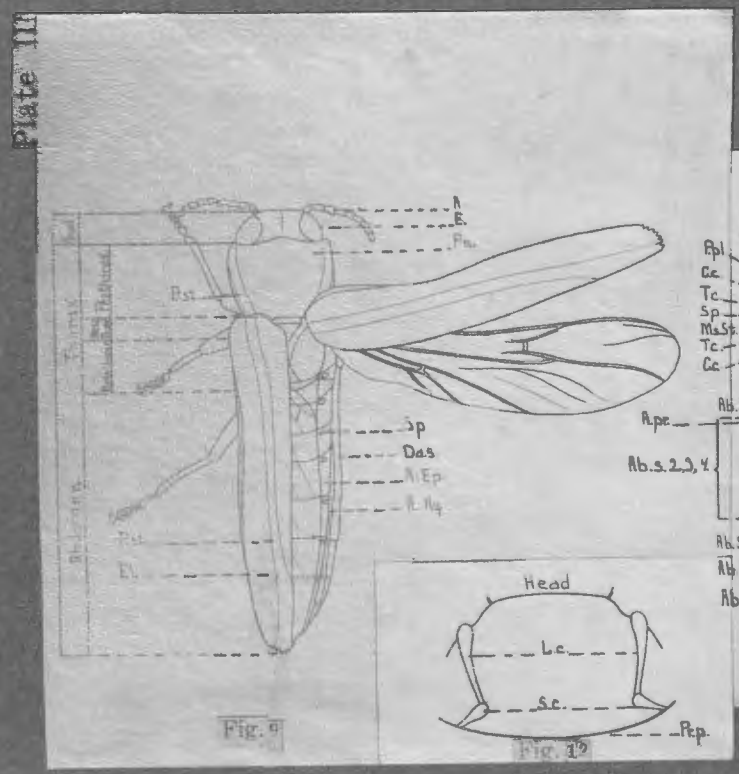
Tc.- Trachantine.

Ta.- Tarsus.

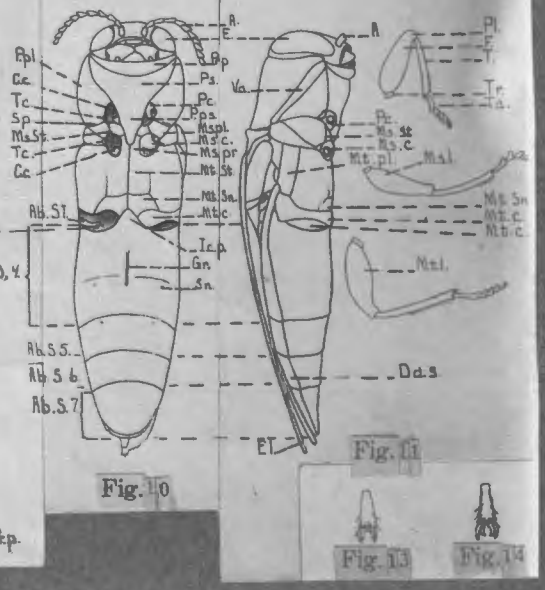
Tr.- Trochanter.

V.a.- Vertical area of prothora

Plate III


A
E.
Pm.
Pst.
Sp
Das
R. Ep
R. M4
Pcu
Cu
Fig. 9

Head
Lc.
Sc.
Rp.
Fig. 12


A.
E.
Ppl
Gc.
Tc.
Sp
Ms.St
Tc.
Cc.
Pp
Ps.
Pc
Pps.
Mt.spl.
Mt.s.c.
Ms.pr
Mt.St.
Mt.Sn.
Mt.c.
Rpc.
Ab.ST.
Ab.s.2,3,4
Tc.p.
Gn.
Sn.
Ab.S.5.
Ab. 5 6
Ab.S.7
ET.
Fig. 10

A
Va.
Pc.
Ms. St
Ms.c
Mt. pl.
Mt.l.
Mt. Sn
Mt.c.
Mt.b.c
Mt.l.
Das
Fig. 11

Pl.
E.
T.
Tr.
Fe.

Fig. 13

Fig. 14

Plate IV.

Fig.15. External genital organs of male protruded. x 12.

Fig.16. External genital organs of female protruded. x 12.

Fig.17. Abdominal pleurites. x 12.

Fig.18. Terminal sclerites of male. x 12.

Fig.19. Eighth and ninth tergites of female. x 12.

Caption.

D.a.s.- Dorsal area of aternite.

E.j.d.- Ejaculatory duct.

E.pl.- Epipleurite.

F.p.- Femora penis.

G.p.- Genital papillae.

Hp.- Hypopleurite.

I.r.- Intermediary rod.

L.v.r.- Long ventral rod of ovipositor.

Op.- Ovipositor.

P.- Penis.

Par.- Paromeron.

P.ph.- Prephragma.

R.tr.9.- Rod of ninth tergite.

Sn.- Sensory pit.

Sp.- Spiracle.

St.- Sternite (1,2,3,5, etc.)

S.v.r.- Short ventral rod.

Tr.- Tergite (1,2,3,4, etc.).

Tl.- Telson.

Plate IV

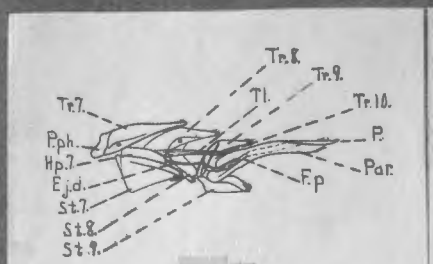


Fig. 15

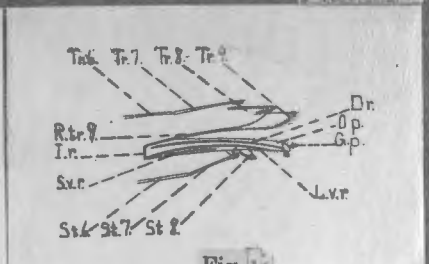


Fig. 16

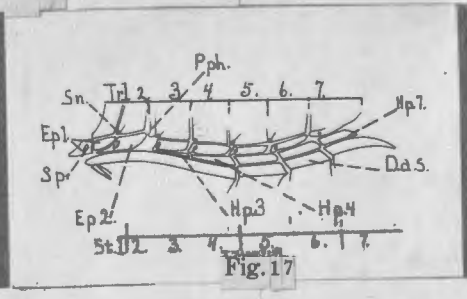


Fig. 17

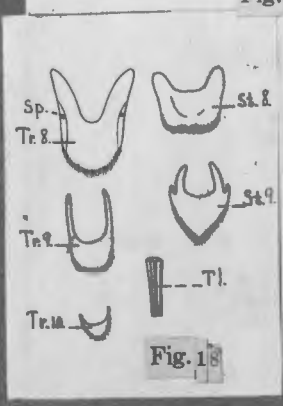


Fig. 18

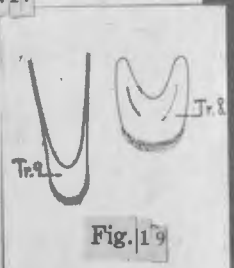


Fig. 19

Plate V.

Fig.30. Diagram of an optical section of the head and thora
x 37.

Fig.31. Longitudinal section of head and thorax(line1,Fig.2
x 37.

Fig.32. Longitudinal section of head and thorax(line 2,Fig.
x 37.

Fig.33. Cross section of head and thorax (line 3, Fig.20)x

Fig.34. Cross section of head and thorax (line 4, Fig.20)x

Caption.

Chitin.

Ectoderm of prothorax.

Ectoderm of head.

As.-	Antennal sclerites (Antennal ring).	Mt.-	Metathorax.
		O.-	Occiput.
C.s.-	Chitinous spines.	O.a.-	Occipital angle.
E.-	Epicranium.	O.e.-	Oesophagus.
E.m.-	Extensor muscles of mandibles.	Ph.-	Pharynx.
Eo.-	Epicranio-occipital apodeme.	Pl.-	Postlabrum.(Epistoma).
F.-	Frons.	Pr.pl.-	Prothoracic pleurum.
F.a.-	Frontal apodeme.	Pr.s.-	Prothoracic sternite.
G.-	Gena.	Pr.t.-	Prothoracic tergum.
G.o.-	Geno-occipital apodeme.	Pt.-	Prothorax.
Gu.-	Gula.(Hypostoma).	R.d.-	Retractor muscle disc.
H.-	Head.	R.m.-	Retractor muscle.
Mst.-	Mesothorax.	T.m.-	Thoracic muscles.

Plate V

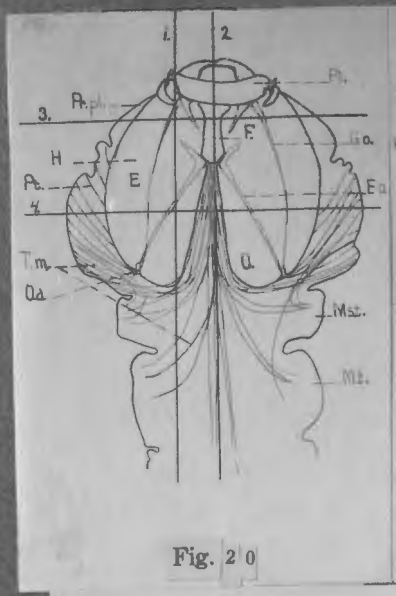


Fig. 20

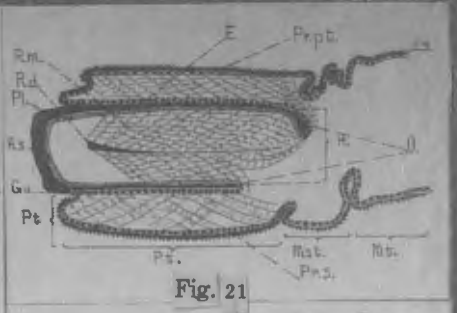


Fig. 21

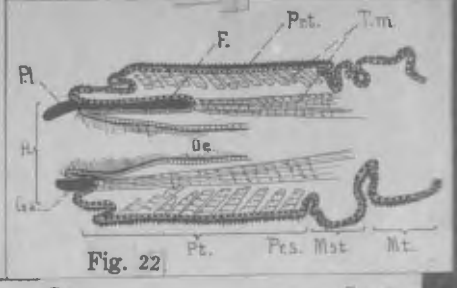


Fig. 22

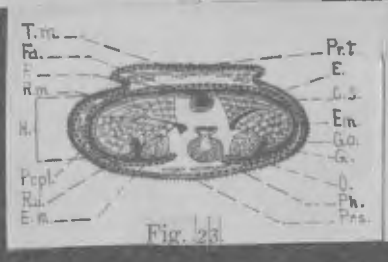


Fig. 23

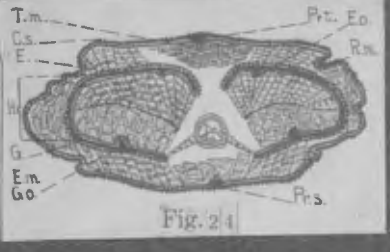


Fig. 24

Plate VI.

Fig.25. Metatergum and wing articulation. x 37.

Fig.26. Metapleurum. x 37.

Fig.27. Mesotergum and wing articulation. x 37.

Fig.28. Right elytron, ventral view. x 12.

Fig.29. Cross section of elytra. x 12.

Caption.

A.c.- Articulation of coxa.

A.g.- Anal groove.

A.m.- Anal margin.

An.f.-Anal fold.

A.n.p.Anterior notal process.

Ax.c.-Axillary cord.

A.v.- Anal vein.

B.d.- Basal declevity.

B.p.- Basal process.

C.f.- Costal fold.

C.g.- Costal groove.

C.h.-Costal head.

Cl.co.-Clavicle condyle.

C.m.- Costal margin.

Cor.co.Coracoid condyle.

Cu.v.-Cubital vein.

C.v.- Costal vein.

Entd.-Entodorsum.

Epim.-Epimerum.

Eps.- Episternum.

F.p.-Flexor plate(Third axillary)

H.a.- Humeral angle.

L.e.- Left elytron.

I.m.e.Inflected margin of episternum.

M.p.- Median plate.

M.v.- Median vein.

N.- Notum.

P.a.- Pleural apodeme.

P.d.- Pleural disc.

Pn.p.- Pronotal process.

P.p.- Pleural process.

P.ph.- Prephragma.

P.ph.d.Prephragmal disc.

Prep.- Preparaptera.

Prsc.- Prescutum.

Ps.cl.-Posrtscutellum.

P.s.- Pleural suture.

Ps.n.- Pseudonotum.

Pst.p.-Postphragma.

R.v.- Radial vein.

R.e.- Right elytron.

Sbcp.-Subscapular plate(Second a

Sc.- Scutum.

Sc.h.- Subcostal head.

Sct.- Scutellum.

Sc.p.-Scapular plate (First axil

Sc.v.-Subcostal vein.

Sp.- Spiracle.

Plate VI

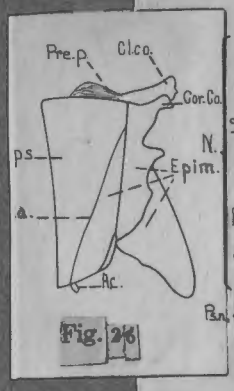


Fig. 26

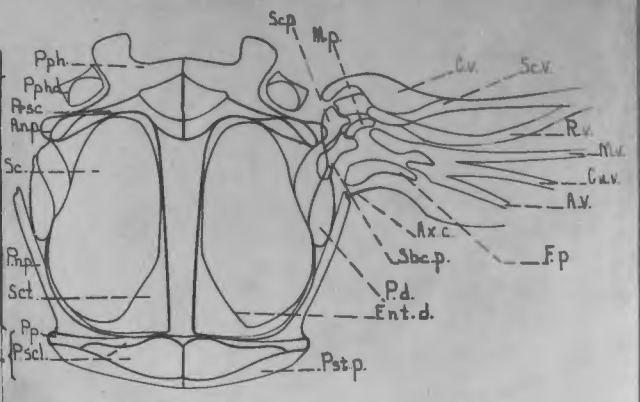


Fig. 25

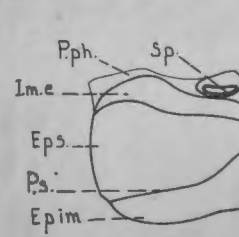


Fig. 30

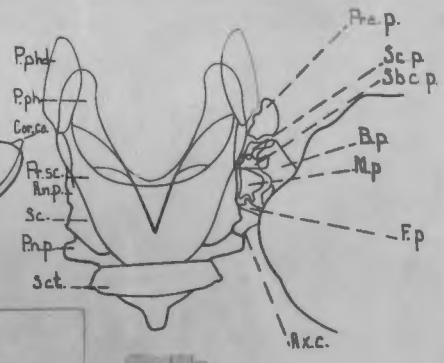


Fig. 27

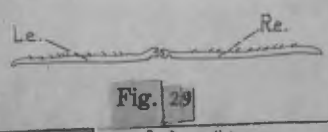


Fig. 29

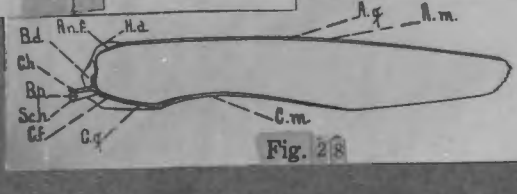


Fig. 28

Plate VII.

Fig.31. Larval head capsule, dorsal. x 37.

Fig.32. Larval head capsule, ventral. x 37.

Fig.33. Adult head, dorsal.

Fig.34. Adult head, ventral.

Caption.

A.f.- Adfrontal bars.

A.- Antenna.

A.s.- Antennal sclerite(Antennal ring).

E.- Eye.

Eo.- Epicranio-occipital apodeme.

Ep.- Epicranium.

Ep.s.-Epicranial suture.

F.a.- Frontal apodeme.

Fr.- Frons.

Ge- Gena.

G.o.- Geno-occipital apodeme.

Gu.- Gula (Hypostoma).

Lr.-Labrum.

Md.- Mandible.

Mnt.- Mentum.

Mx.p.- Maxillary palp.

O.a.- Occipital angle.

O.c.- Occiput.

O.f.- Occipital foramen.

Pl.- Postlabrum.(Epistoma).

Plate VII

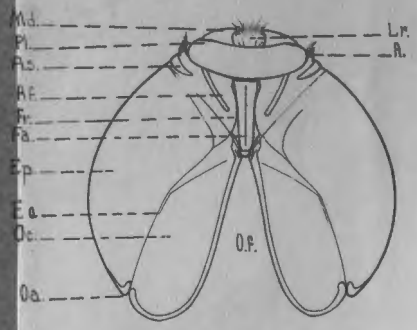


Fig. 31

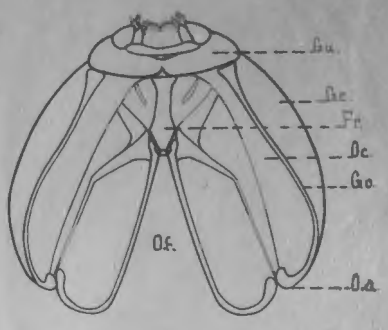


Fig. 32

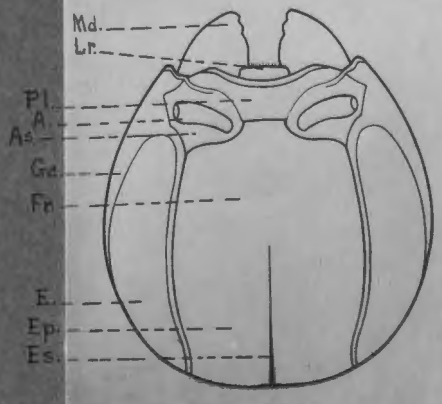


Fig. 33

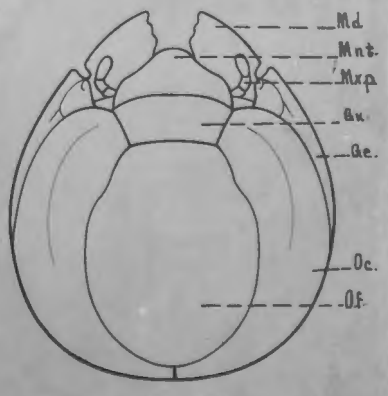


Fig. 34

Plate VIII.

Fig.35. Larval mouth parts. x 37.

Fig. 36. Adult mouth parts.

Caption.

A.t.- Apical tooth.

Ca.- Cardo.

D.f.- Dorsal fossa of mandible.

Ga.- Galea.

H.b.- Hypopharyngeal bracon.

La.- Lacinia.

Lb.p.-Labial palp.

Li.- Labium.

Lr.- Labrum.

Men.- Mentum.

Md.- Mandible.

Md.- Mandible.

Md.t.- Median tooth.

Mp.- Maxillary palp.

M.t.- Molar tooth.

P.d.- Protractor muscle disc.

Pf.- Palpifer.

R.d.- Retractor muscle disc.

S.m.- Submentum.

St.- Stipes.

V.c.- Ventral condyle of mandib

Plate VIII

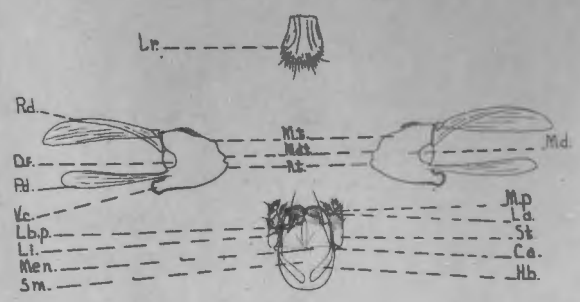


Fig. 35

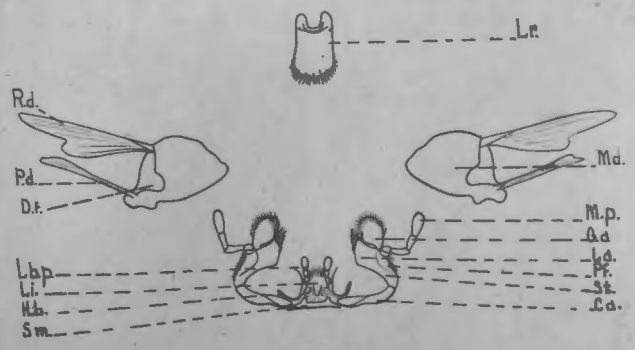


Fig. 36